Design and Numerical Simulation of Tube in Tube Heat Exchanger

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Abstract: **Heat exchangers have always been an important part to the lifecycle and operation of many systems. A heat exchanger is a device built for efficient heat transfer from one medium to another medium. Shell and tube heat exchanger is an indirect contact type heat exchange as it consists of a series of tubes, through which one of the fluids runs. Shell and tube heat exchange which is the majority type of liquid-to-liquid heat exchanger with baffle for induced turbulence and higher heat transfer coefficient. Shell and Tube heat exchangers are having special importance in boilers, oil coolers, condensers, pre- heaters, power plant, chemical plants, petrochemical plants and automotive applications and refrigeration and air conditioning industry. This paper discusses the design and analysis of shell and tube heat exchangers by considering different fluids, Nano fluid, Hybrid Nano fluids (fluids has water(h_2O), Nano fluids has aluminium-oxide and copper (Al_2O_3 and cu) and Hybrid Nano fluids has aluminium oxide -copper (Al_2O_3-cu/h_2O)) which is mixed as distilled water (h_2O) and their ability to transfer heat from the surface. Temperature distribution, heat flux and thermal gradient in heat transfer analysis, also when we do structural analysis for heat exchanger by using ANSYS Fluent CFD analysis software.**

Key Words: **Fluid, Nanofluid, Materials, Shell and tube heat exchanger.**

I. INTRODUCTION

HEAT EXCHANGER: - A heat exchanger is a system used to transfer heat between a source and working fluid. Heat exchangers are used in both cooling and heating processes. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Another example is the heat sink, which is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant.

TYPES OF HEAT EXCHANGERS: Heat exchangers are of two types:
1.Direct contact type Heat Exchanger: Direct contact heat exchangers involve heat transfer between hot and cold streams of two phases in the absence of a separating wall
2.InDirect contact type Heat Exchanger: Where both media are separated by a wall through which heat is transferred so that they never mix, Indirect contact heat exchanger.
There are some of the heat exchangers are given below:
• Double-pipe heat Exchanger • Shell and Tube Heat Exchanger • Plate Heat Exchanger • Tube in Tube Heat Exchanger as shown in Fig 1.• Condensers and Boilers Heat Exchangers 777

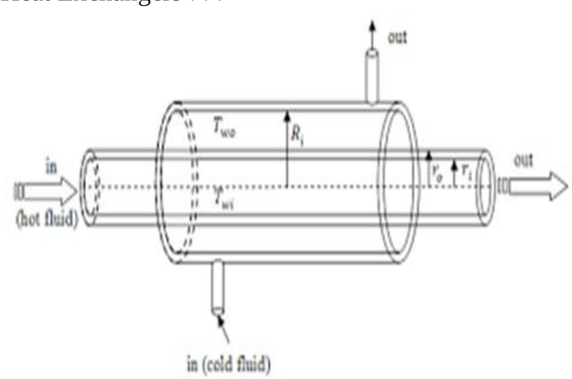

Fig 1 Tube in Tube Heat Exchanger

Advantages of Tube in Tube Heat Exchangers

• Low maintenance costs. • High working pressure. • High working temperatures. • Processing of particulate or fibre products. • High security in aseptic processes. • Easy inspection and disassembly.

II.LITERATURE REVIEW

Erica Jacqueline Fernandes et.al [1] In this paper discusses the design and analysis of shell and tube heat exchangers by considering different material and their ability to transfer heat from the surface. So, baffles play an important role to analyse the performance of the heat exchangers and it is possible to improve their heat transfer capabilities. Mehdi Bahiraei et.al [2] In this paper aims to research the thermohydraulic characteristics and performance index for flow of the nanofluids containing varied particle shapes including cylinder, blade, brick, platelet, and Oblate Spheroid (OS) in a shell and tube heat exchanger (STHX). Arjun Kumar Prasad et.al [3] The main objective in this is heat exchanger design is the estimation of the minimum heat transfer area required for a given heat duty, as it governs the overall cost of the heat exchanger. Haoshan Ren et.al [4] In this paper it talks about the presents the development, experimental testing, and numerical investigation of water-based phase change material (PCM) thermal energy storage (TES) using the shell-and-tube design with different tube layouts including single serpentine, double serpentine, and spiral. Hussein M. Maghrabie et.al [5] In this paper it mainly investigates about the effect of the inclination angle (ɵ) of a shell and helically coiled tube heat exchanger (SHCT-HE) on its performance utilizing based water Al_2O_3 /water, and SiO_2/water nanofluids is investigated experimentally. V.Raju et.al [6] In this paper the procedure of specifying a design, heat transfer area and pressure drops and checking whether the assumed design satisfies all requirements or not. The purpose of this thesis work is how to design the oil cooler (heat exchanger) especially for shell and-tube heat exchanger which is the majority type of liquid-to-liquid heat exchanger. P.S.Gowthaman et.al [7] In this paper says about the in this project work the analyse of two different baffle -in a Shell and Tube Heat Exchanger done by ANSYS FLUENT. Shell and tube heat exchanger has been widely used in many industrial applications such as electric power generation, Refrigeration and Environmental Protection and Chemical Engineering. A.O. Adelaja et.al [8] In this paper, the Most of the attempts made at designing shell and tube heat exchangers have been limited to thermal-hydraulic design. This study however, considers both the thermal and mechanical design of the E-type shell and tube heat exchanger with the aid of computer programming. RNSV. Ramakanth et.al [9] This paper focuses on the various researches on CFD analysis in the field of heat exchanger. Shell and tube heat exchanger is an indirect contact type heat exchange as it consists of a series of tubes, through which one of the fluids runs. Baydaa Rashid Ismael et.al [10] In this analysis is done for heat exchanger with baffle and without baffle also used four materials for tubes (brass, nickel, carbon steel, stainless steel) and observed the heat transfer rate is increased for heat exchanger with baffle and when we used brass material. S. Anitha et.al [11] Influence of nanoparticle volume concentration and proportion on heat transfer performance (HTP) of Al_2O_3 – Cu/water hybrid nanofluid in a single pass shell and tube heat exchanger is analysed. Multiphase mixture model is adopted to model the flow then the results indicate that optimized nanoparticle volume concentration and proportion dominate HTP of hybrid nanofluid. Beneth C et.al [12] This research aimed at optimizing the input conditions of a shell and tube heat exchanger. To achieve this, a CFD analysis was run on the model using Solid Works flow simulation tool in order to generate a series of responses for 20 input variables. Jaafar Albadr et.al [13] This article reports an experimental study on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and different volume concentrations of Al_2O_3 nanofluid (0.3–2) % flowing in a horizontal shell and tube heat exchanger counter flow under turbulent flow conditions are investigated. Jaafar Albadr et.al [13] This article reports an experimental study on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and different volume concentrations of Al_2O_3 nanofluid (0.3–2) % flowing in a horizontal shell and tube heat exchanger counter flow under turbulent flow conditions are investigated. Nishant Kumar et.al [15] Heat transfer characteristics of Fe_2O_3/water and Fe_2O_3/EG nanofluids were measured in a shell and tube heat exchanger under laminar to turbulent flow condition. In the shell and tube heat exchanger, water and ethylene glycol-based

Fe_2O_3 nanofluids with 0.02%, 0.04%, 0.06% and 0.08% volume fractions were used as working fluids for different flow rates of nanofluids. Roghayeh Lotfi et.al [16] Heat transfer enhancement of multi-walled carbon natube (MWNT)/water nanofluid in a horizontal shell and tube heat exchanger has been studied experimentally. Carbon nanotubes were synthesized by the use of catalytic chemical vapor deposition (CCVD) method over Co–Mo/MgO nano catalyst. M. Muneeshwaran et.al [17] In this paper, a state-of-the-art review on the use of hybrid nanofluid in various heat transfer applications is presented. The first part of the article summarizes the existing research works on the preparation and synthesis of various hybrid nanocomposites and hybrid nanofluids. Subsequently, density, specific heat, viscosity, and thermal conductivity values of different hybrid nanofluids are tabulated, serving as a database. K.Somasekhar et.al [18] This paper discusses the multi pass shell and tube heat exchanger with 3 tubes modelling is done using CATIA and meshing has done using ICEM CFD software, simulations has done by using CFD-FLUENT software. O. Labbadlia et.al [19] The behaviour of the fluid inside the internal circulation system of a shell and tube heat exchanger is complex due to the influence of many factors. The flow distribution has a significant influence on the performance of fluidic apparatus such as shell and tube heat exchangers. Adnan Mohammed Hussein [20] The results show that the friction factor decreases when there is an increase in the flow rate and it increases when the volume concentration of nanofluid is increased while the Nusselt number increases by increasing of the flow rate and volume concentration of nanofluid.

By using these literature surveys, we can say that there are different types of materials, designs are used on the shell and tube heat exchanger and different types of baffles are used and different types of fluids are also used in this heat exchanger. These journals are taken as reference and thus to make the design, modelling and analyse the different fluids are used in the shell and tube heat exchanger that is fluids are added to the base fluid, Nano fluids added to the base fluid and Hybrid Nano fluids are added to the base fluids, which is distilled water, and to increase the heat transfer rate by using different materials and fluids causes the significant enhancement of heat transfer characteristics.

III. METHODOLOGY

In this type, there are two fluids with different temperatures, one of them flow through tubes and another flow-through shell. Heat is transferred from one fluid to another through the tube walls, either from the tube side to the shell side or vice versa.

The main methods of heat exchanger design and analysis are those of the Logarithmic Mean Temperature Difference (LMTD) method and the effectiveness (ε) Number of Transfer Units (e-NTU) method, with the latter being used for detailed application here. The procedure to be followed with the LMTD method

- Select the type of heat exchanger.
- Calculate any unknown inlet or outlet temperatures and the heat transfer rate.
- Calculate the log-mean temperature difference and the correction factor, if necessary.
- Calculate the overall heat transfer coefficient.
- Calculate the heat transfer surface area.
- Calculate the length of the tube or heat exchanger.

IV.MODELLING AND ANALYSIS

First the geometry of the model is created in ANSYS workbench. Fluid flow (fluent) module is selected from the workbench. The design modeler opens as a new window when the geometry is double clicked.

A. Geometrical modelling: Sketch, Draw, Dimensions, Extrude, Fill, Boolean (subtract).
B. Meshing: Generate Mesh, Select faces or highlight faces.
C. Setup: General, Models, Materials, Call Zone Conditions, Boundary Conditions.
D. Solution: Methods, Initialization, Run Calculation.
E. Results: Velocity vectors, Temperature Contour, Streamline.

A. The tube in tube heat exchanger dimensions is given in the below Table 1 and thermal properties of a heat exchanger as shown below in Table 2.

Table 1 Dimension of tube in tube heat exchanger.

Parameters	Values
Heat Exchanger type	Shell and Tube Heat Exchanger with single pass
Outer diameter of a shell	22mm

Inner diameter of a shell	20mm
Outer diameter of tube	12.5mm
Inner diameter of a tube	10.5mm
Depth/length of the shell	1000mm
Depth/length of the tube	1000mm

By using the dimensions modelling is prepared as shown in Fig 2.

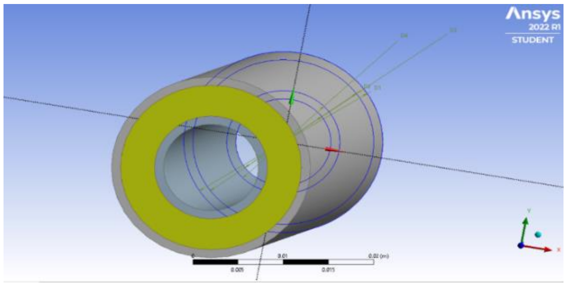

Fig 2 Modelling of a Tube in Tube heat exchanger

B.Mesh Optimization with Ansys Software: Meshing, also known as mesh generation as shown in below Fig 3, is the process of generating a two-dimensional and three-dimensional grid; it is dividing complex geometries into elements that can be used to discretize a domain.

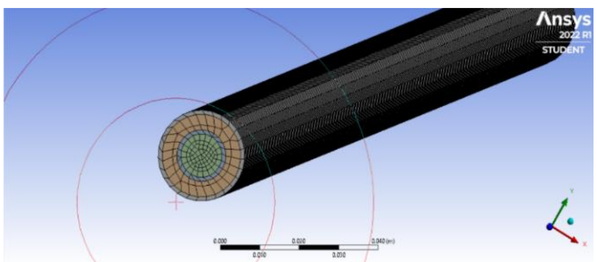

Fig 3 Meshing

C. In the setup it follows models in that 'ON' the energy equation on position and viscous as laminar.Materials for fluid as water and solid tube material as aluminium. Then enter the thermalphysical properties of water then followed by cell zone conditions are fluid: cold and hot fluids as water vapour and solid as aluminium.boundary conditions are inlet :enter the cold and hot inlet velocities and thermal temperatures values as shown in the Table 2.

Table 2 Thermophysical properties

Properties	Fluids	Nano fluids	
	Water	Al_2O_3	CuO
Density ρ (kg/m^3)	998.2	3970	8933
Specific heat Cp (J/kg k)	4182	765	703
Thermal conductivity K (W/m K)	0.6	40	400
Viscosity (Kg/m s)	0.001003	-	-
Velocity Magnitude (m/s)	1.373	0.0291	0.034
Inlet temperature of shell (k) Cold fluid	288	301	301
Inlet temperatures of tube (k)Hot fluid	373	348	353

D.In the solution, models as simple and initialization as standard compute from is hot inlet then click on initialize and then calculations -run calculations number of iterations is 500 then click on calculate.

NANO-FLUID is taken as $Al_2O_3$and Copper(cu).
Change the fluid materials (C.c) – cold fluid as Al_2O_3 and hot fluid as water vapour then enter the thermal properties of a $Al_2O_3$and water vapour. Then cell zone conditions are fluid – cold fluid as $Al_2O_3$and hot as water vapour, no change the solid materials always aluminium. Give the boundary conditions inlet- cold inlet as well as hot inlet velocities, temperatures and number of iterations as 500. Same procedure for copper.

HYBRID NANO FLUID is taken as Aluminium-oxide-Copper/water (Al_2o_3-cu/h_2o). Now, fluid is taken as combination of aluminium oxide and copper is mixed with a distilled water then the Fluid is known as Hybrid Nano Fluid, procedure is same as well as sketching and meshing and setup models, change the materials, cell Zone conditions and boundary conditions then the results are as same procedure.

Change the fluid materials (C.) – cold fluid as Al_2O_3-cu and hot fluid as water vapour then enter the thermal properties of a Al_2O_3-cuand water vapour. Then cell zone conditions are fluid – cold fluid as Al_2O_3-cuand hot as water vapour, no change the solid materials always aluminium.

V. CALCULATIONS

Formulas for the Hybrid Nano fluids as shown in the below Table 3, the table shows the nano fluid is converted to Hybrid nano fluid by using formulas as shown in below Table 4.

Table3: Thermophysical properties of nanofluid and hybrid nanofluid

Nano fluid	Hybrid Nanofluid
$\rho_{nf} = \varphi_S \rho_s + (1 - \varphi_S)\rho_f$	$\rho_{hnf} = \varphi_{S1}\rho_{s1} + \varphi_{S2}\rho_{s2} + (1 - \varphi_S)\rho_{nf}$
$\mu_{n_f} = \mu_f(1 + 2.5\varphi_s)$	$\mu_{hn_f} = \mu_{nf}(1 + 2.5\varphi_{s1} + \varphi_{S2})$

$Cp = (1-\varphi_s)(\rho Cp) + \varphi_S(\rho Cp)s$	$Cp = (1-\varphi_s)(\rho Cp)n_f + \varphi_{S1}(\rho cp)_{s_1} + \varphi_{S2}(\rho cp)_{s_2}$
$\frac{k_{n_f}}{k_f} = \frac{K_s+(n-1)k_f-(n-1)\varphi_S(k_f-K_s)}{K_s+(n-1)k_f+\varphi_S(k_f-K_s)}$	$\frac{k_{hn_f}}{k_{bf}} = \frac{K_{s2}+(n-1)k_f-(n-1)\varphi_{S2}(k_{bf}-K_{s2})}{K_{s2}+(n-1)k_{bf}+\varphi_{S2}(k_{bf}-K_{s2})}$; $\frac{k_{bf}}{k_f} = \frac{K_{s1}+(n-1)k_f-(n-1)\varphi_{S1}(k_f-K_{s1})}{K_{s1}+(n-1)k_f+\varphi_{S1}(k_f-K_{s1})}$

Table 4: Thermophysical properties of Hybrid Nano-fluid

Properties	values
Density ρ (kg/m^3)	1009.1066
Specific heat Cp (J/kg k)	4175428.404
Thermal conductivity K (W/m K)	1
Viscosity (Kg/m s)	1.00099
Velocity Magnitude (m/s)	0.12
Inlet temperature of shell (k) Cold fluid	301
Inlet temperatures of tube (k) Hot fluid	348

VI. RESULTS

The results obtain by the analysis of shell and tube heat exchanger are given below, described in the form of figures. The heat transfer and flow characteristics of a single pass shell and tube heat exchanger pipe can be observed from the heat transfer rates as shown in below Fig 4 shows the Nano fluid Al_2O_3transfer heat to surroundings.

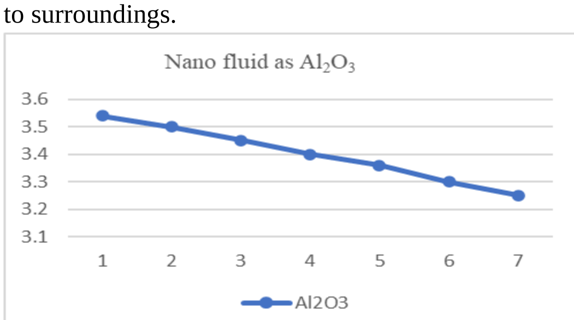

Fig 4 Temperature distribution in Hybrid Nanofluids

This shows the Hybris nano fluid transfer the heat from tube to surroundings it takes less time.

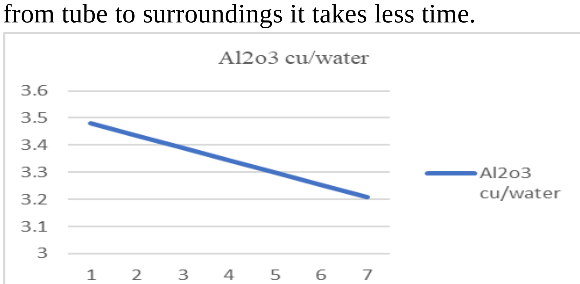

Fig 5Temperature distribution in Hybrid Nanofluids

The Fig 6 shows the comparison between the fluids and Nano fluids, Nanofluids is less time to transfer the heat as compared to fluids. So, nano fluids are best to transfer the heat.

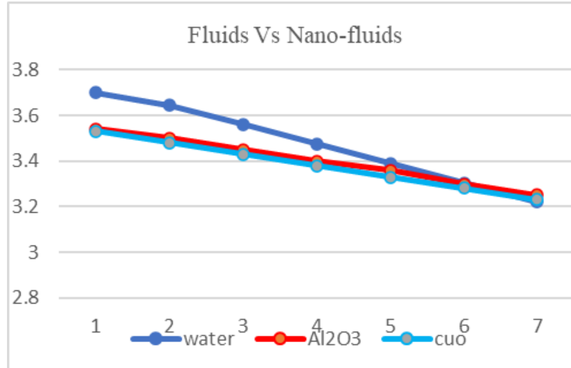

Fig 6 Temperature distribution in fluids and nano fluids

The Fig 7 shows the comparison between the Nano fluids and Hybrid Nano fluids, Nanofluids is less time to transfer the heat as compared to fluids but this Hybrid nano fluids are less time taken to transfer the heat as compared to Nano fluids So, Hybrid nano fluids are more heat transfer rate.

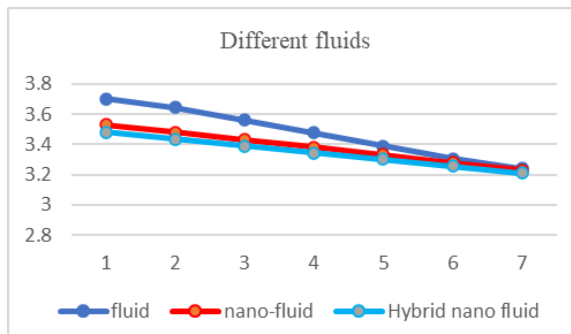

Fig 7 Temperature distribution in fluids, Nanofluids & Hybrid Nanofluids

Hybrid Nano fluids transfer the more heat transfer rate and take less time to transfer the heat as compared to nano fluids and nano fluids heat transfer is more as compared to fluids. That's-why Hybrid nano fluids are take less time as well as more heat transfer can be obtained. Hybris nano fluids have more major advantage used in the Heat Exchanger.

VII. CONCLUSION

This work investigates the heat transfer and flow characteristics of a shell and tube heat exchanger with single pass for counter flow using CFD methodology. The effect of mass flow rate in the inner tube and fluids, Nanofluids and Hybrid Nanofluids are studied and the conclusions are:

- Use Hybrid Nano fluids has more heat transfer rate than compared to Nano fluids and fluids.
- Al2O3-Cu/water system is considered is one of the most promising for industry scale development.
- The result obtained was used to generate an objective function which is an optimization model for maximizing the efficiency of the unit.
- The selection of the material has a significant impact on heat transfer rate in case of shell and tube heat exchangers.
- From this research study it can be concluded that shell and baffles made of copper has performed better as compared to stainless steel and aluminium
- Addition of nanoparticles increases the heat transfer area of the fluid, and it increases the convective heat transfer of nanofluids. This is because the nanoparticles are near the surface of the internal wall of the heat exchanger and hence fast heat exchange takes place. Nanofluids can be considered as next-generation heat transfer fluids in heat transfer applications.

REFERENCE

[1] Erica Jacqueline Fernandes and Sachidananda Hassan Krishanmurthy “Design and analysis of shell and tube heat exchanger”, International Journal for Simulation and Multidisciplinary Design Optimization (IJSMDO), Volume 13, Issue 15, Page No. 1-8, Feb 2022.

[2] Mehdi Bahiraei, Mohammad Naseri, Ali Monavari “A CFD study on thermohydraulic characteristics of a nanofluid in a shell-and-tube heat exchanger fitted with new unilateral ladder type helical baffles”, Elsevier, Page No. 1-17, Apr 2021.

[3] Arjun Kumar Prasad, Mr. Kaushik Anand, “Design & Analysis of Shell & Tube Type Heat Exchanger”, International Journal of Engineering Research & Technology (IJERT), Volume 9, Issue 01, ISSN: 2278-0181, Page No.524-539, January-2020.

[4] Haoshan Ren, Ming He, Wenye Lin, Luwei Yang, Weihua Li, Zhenjun Ma,” Performance investigation and sensitivity analysis of shell-and-tube phase change material thermal energy storage”, Elsevier, Page No.1-15, Nov 2020.

[5] Hussein M. Maghrabie, M. Attalla, Abrar A. A. Mohsen,” Performance assessment of a shell and helically coiled tube heat exchanger with variable orientations utilizing different nanofluids”, Elsevier, Page No 1-16, Sep 2020.

[6] V.RajNarendar Naik, “Thermal Design & Analysis Of Shell And Tube Heat Exchanger”, Journal of Emerging Technologies and Innovative Research (JETIR)Volume 4, Issue 11, ISSN: 2349-5162, Page No.722-728, Nov 2017.

[7] P.S..Gowthaman and S.Sathish, “Analysis of Segmental and Helical Baffle in Shell and tube Heat Exchanger”, International Journal of Current Engineering and Technology, Issue 2, ISSN 2277 – 4106, Page No.625-628, Feb 2014.

[8] A.O. Adelaja, S. J. Ojolo and M. G. Sobamowo,” Computer Aided Analysis of Thermal and Mechanical Design of Shelland Tube Heat Exchangers”, Advances in Materials and Systems Technologies III, Volume 367, Page No. 731-737, Oct 2011.

[9] Baydaa Rashid Ismael, Dr.Aruna Kumari, “Design and Analysis of Heat Exchanger”, International Journal os scientific Engineering and Technology Research, Volume 03, Issue 20, ISSN 2319-8885, Page No. 4181-4187, Sep 2014.

[10] RNSV. Ramakanth, K. Rajesh Kumar,” Design and CFD Analysis of Shell and Tube HeatExchanger”, International Journal of Science and Research (IJSR), Volume 7, Issue 1, ISSN 2319-7064, Page No. 638-641, January 2018.

[11] S. Anitha, Tiju Thomas,V. Parthiban, M. Pichumani,” What dominates heat transfer performance of hybrid nanofluid in single pass shell and tube heat exchanger?”, Elsevier, Page No. 1-11, Oct 2019.

[12] Beneth C. Chukwudi, Martins B. Ogunedo, “Optimization of the Inlet Conditions of a Shell and Tube Heat Exchanger”, International Journal of Research and Review, Volume 5, Issue 6, ISSN 2349-9788, Page N0. 145-150, June 2018.

[13] Jaafar Albadr, SatinderTayal, MushtaqAlasadi, “Heat transfer through heat exchanger using Al2O3 nanofluid at different concentrations”, Elsevier, Page No.38-44, August 2013.

[14] B. Farajollahi, S.Gh. Etemad, M. Hojjat, “Heat transfer of nanofluids in a shell and tube heat

exchanger", Elsevier, Page No. 12-17, November 2009.

[15] Nishant Kumar, Shriram S. Sonawane, "Experimental study of Fe2O3/water and Fe2O3/ethylene glycol nanofluid heat transfer enhancement in a shell and tube heat exchanger", Elsevier, Page No. 1-8,2016.

[16] RoghayehLotfi, Ali Morad Rashidi, AzadehAmrollahi," Experimental study on the heat transfer enhancement of MWNT-water nanofluid in a shell and tube heat exchanger", Elsevier, Page No. 108-111, 2012.

[17] M. Muneeshwaran, G. Srinivasan, P. Muthukumar, Chi-Chuan Wang, "Role of hybrid-nanofluid in heat transfer enhancement – A review", Elsevier, Page No. 1-30, May 2021.

[18] K. Somasekhar, K.N.D. Malleswara Rao, V. Sankararao, Raffi Mohammed, M. Veerendra and T. Venkateswararao "A CFD Investigation of Heat Transfer Enhancement of Shell and Tube Heat Exchanger Using Al2o3-Water Nanofluid", Elsevier, Page No. 1057-1062, July 2016.

[19] O. Labbadlia, B. Laribia, B. Chetti, P. Hendrick," Numerical Study of the Influence of Tube Arrangement on the Flow Distribution in the Header of Shell and Tube Heat Exchangers", Applied Thermal Engineering, Page No. 1-25, July 2017.

[20] Adnan Mohammed Hussein, "Thermal performance and thermal properties of hybrid nanofluid laminar flow in a double pipe heat exchanger", Experimental Thermal and Fluid Science, Page No. 1-24, May 2017.